

IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements

Sponsor

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Abstract: Performance and functional requirements for a communications-based train control (CBTC) system are established in this standard. A CBTC system is a continuous, automatic train control system utilizing high-resolution train location determination, independent of track circuits; continuous, high-capacity, bidirectional train-to-wayside data communications; and trainborne and wayside processors capable of implementing automatic train protection (ATP) functions, as well as optional automatic train operation (ATO) and automatic train supervision (ATS) functions. In addition to CBTC functional requirements, this standard also defines headway criteria, system safety criteria, and system availability criteria for a CBTC system.

Keywords: communications, signaling, train control

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Introduction

[This introduction is not part of IEEE Std 1474.1-1999, IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements.]

This introduction provides some background on the rationale used to develop this standard. This information is meant to aid in the understanding, usage, and applicability of this standard.

Conventional signaling/train control systems rely almost exclusively on track circuits to detect the presence of trains. Information on the status of the track ahead is provided to train operators either through wayside signals or trainborne cab signals. Ensuring compliance with the signals is achieved through operating procedures, wayside automatic train stops, or trainborne supervisory equipment linked to the train's braking system. These conventional systems are effective in providing train protection, but are not particularly efficient in maximizing the utilization of the rail transit infrastructure, as a result of a number of fundamental limitations, specifically

- a) The location of trains can only be determined to the resolution of the track circuits; if any part of a track circuit is occupied by a train, the whole track circuit must be assumed to be occupied by the train. Track circuits can be made shorter, but each additional track circuit requires additional wayside hardware, so there is an economical and practical limit to the number of track circuits that can be provided.
- b) The information that can be provided to a train is limited to a small number of wayside signal aspects, or a small number of speed codes in a cab signal system.
- c) For a wayside signal system with automatic train stops, but without continuous cab signaling, enforcement is intermittent.

Communications-based train control (CBTC) systems overcome these fundamental limitations of conventional track circuit-based systems and, therefore, permit more effective utilization of the transit infrastructure. This is accomplished, for example, by allowing trains to operate safely at much closer headways, by permitting greater flexibility and greater precision in train control, and by providing continuous safe train separation assurance and overspeed protection. Additional benefits of CBTC technology include the economical support of automatic train operations (both on the mainline and in maintenance yards), improved reliability, and reductions in maintenance costs through a reduction in wayside equipment and real-time diagnostic information. The basic characteristics of a CBTC system include the following:

- a) Determination of train location, to a high degree of precision, independent of track circuits.
- b) A geographically continuous train-to-wayside and wayside-to-train data communications network to permit the transfer of significantly more control and status information than is possible with conventional systems.
- c) Wayside and trainborne vital processors to process the train status and control data and provide continuous automatic train protection (ATP). Automatic train operation (ATO) and automatic train supervision (ATS) functions can also be provided, as required by the particular application.

Although the benefits of CBTC technology are recognized, there are currently no independent standards defining the performance and functional requirements that need to be satisfied by CBTC systems in order to realize enhanced performance, availability, train operational flexibility and train protection. This standard has been developed to address this.

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Contents

1. Overview.....	1
1.1 Scope.....	1
1.2 Purpose.....	1
1.3 Existing applications.....	1
2. References.....	1
3. Abbreviations, acronyms and definitions	2
3.1 Definitions.....	2
3.2 Abbreviations and acronyms.....	4
4. General requirements	5
4.1 Characteristics of CBTC systems	5
4.2 Categorization of CBTC systems.....	5
4.3 Range of applications.....	5
4.4 Train configurations.....	5
4.5 Train operating modes	6
4.6 Transitions between operating modes.....	8
4.7 Train operating speeds	8
5. Performance requirements	9
5.1 CBTC factors contributing to achievable headways.....	9
5.2 CBTC factors contributing to achievable trip times	9
5.3 System safety requirements	10
5.4 System assurance requirements	11
5.5 Environmental requirements.....	14
6. Functional requirements.....	14
6.1 ATP functions	15
6.2 ATO functions	21
6.3 ATS functions	22
6.4 Interoperability interface requirements.....	26
Annex A (informative) Bibliography.....	27
Annex B (informative) Example functional block diagram for a typical CBTC system.....	28
Annex C (informative) Typical CBTC parameters.....	29
Annex D (informative) Typical safe braking model.....	30

IEEE Standard for Communications-Based Train Control (CBTC) Performance and Functional Requirements

1. Overview

This standard establishes performance and functional requirements for a communications-based train control (CBTC) system. It is divided into six clauses. Clause 1 describes the scope and purpose of this standard. Clause 2 lists references that are useful in applying this standard. Clause 3 provides definitions that are either not found in other standards, or have been modified for use with this standard. Clause 4 defines the general operating requirements for CBTC systems, including train operating modes to be supported. Clause 5 defines the performance requirements for CBTC systems, including headway criteria, system safety criteria, and system availability criteria. Clause 6 defines the functional requirements for CBTC systems, including automatic train protection (ATP) functions, automatic train operation (ATO) functions, and automatic train supervision (ATS) functions.

1.1 Scope

This standard establishes a set of performance and functional requirements necessary for enhancing performance, availability, operations, and train protection using a CBTC system.

1.2 Purpose

There are currently no independent standards defining the performance and functional requirements to be satisfied by CBTC systems. This standard will enhance performance, availability, operations, and train protection, and will facilitate new CBTC applications.

1.3 Existing applications

Existing CBTC installations and projects in progress prior to the effective date of this standard need not comply with the new or revised requirements of this edition, except where specifically required by the authority having jurisdiction.

2. References

This standard shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply. In case of a conflict between this standard and the referenced document, this standard shall take precedence. Those provisions of the referenced documents that are not in conflict with this standard shall apply as referenced.

IEEE Std 100-1996, The IEEE Standard Dictionary of Electrical and Electronics Terms, Sixth Edition.¹

IEEE P1483 (Draft D0.17, 04 June 1999), Draft Standard for Safety Considerations for Software Used in Rail Transit Systems.

IEEE Std. 1477-1998, IEEE Standard for Passenger Information System for Rail Transit Vehicles.

IEEE Std 1475-1999, IEEE Standard for the Functioning of and Interfaces Among Propulsion, Friction Brake, and Train-borne Master Control on Rapid Transit Vehicles.

MIL-STD-882C, System Safety Program Requirements.²

3. Abbreviations, acronyms and definitions

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE Std 100-1996 should be referenced for terms not defined in this clause.

3.1.1 authority having jurisdiction: The entity that defines the contractual (including specification) requirements for the procurement.

3.1.2 automatic train control (ATC): The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC must include automatic train protection, and may include automatic train operation and/or automatic train supervision.

3.1.3 automatic train operation (ATO): The subsystem within the automatic train control system that performs any or all of the functions of speed regulation, programmed stopping, door control, performance level regulation, or other functions otherwise assigned to the train operator.

3.1.4 automatic train protection (ATP): The subsystem within the automatic train control system that maintains fail-safe protection against collisions, excessive speed, and other hazardous conditions through a combination of train detection, train separation, and interlocking.

3.1.5 automatic train supervision (ATS): The subsystem within the automatic train control system that monitors trains, adjusts the performance of individual trains to maintain schedules, and provides data to adjust service to minimize inconveniences otherwise caused by irregularities.

NOTE—The ATS subsystem also typically includes manual and automatic routing functions.

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.standards.ieee.org/>).

²MIL publications are available from Customer Service, Defense Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.

3.1.6 auxiliary wayside system: A back-up or secondary train control system, capable of providing full or partial automatic train protection for trains not equipped with trainborne communications-based train control (CBTC) equipment, and/or trains with partially or totally inoperative trainborne CBTC equipment. The auxiliary wayside system may include trainborne equipment and may also provide broken rail detection.

3.1.7 basic operating unit: (A) A single vehicle designed for independent operation. (B) A permanent or semipermanent combination, designed for independent operation, consisting of two or more vehicles of one or more types.

3.1.8 brake, emergency: Fail-safe, open-loop braking to a complete stop, with an assured maximum stopping distance considering all relevant factors. Once the brake application is initiated, it is irretrievable; i.e., it cannot be released until the train has stopped or a predefined time has passed.

3.1.9 brake, (maximum) service: A nonemergency brake application that obtains the (maximum) brake rate that is consistent with the design of the brake system, retrievable under the control of master control.

3.1.10 car: *See:* vehicle.

3.1.10 civil speed limit: The maximum speed authorized for each section of track, as determined primarily by the alignment, profile, and structure.

3.1.12 communications-based train control: A continuous automatic train control system utilizing high-resolution train location determination, independent of track circuits; continuous, high capacity, bidirectional train-to-wayside data communications; and trainborne and wayside processors capable of implementing vital functions.

3.1.13 commuter rail: A passenger railroad service that operates within metropolitan areas on trackage that usually is part of the general railroad system. The operations, primarily for commuters, are generally run as part of a regional system that is publicly owned, or by a railroad company as part of its overall service.

3.1.14 consist: The makeup or composition (number and specific identity) of individual units of a train.

3.1.15 dwell time: The time a transit unit (vehicle or train) spends at a station or stop, measured as the interval between its stopping and starting.

3.1.16 fail-safe: A design philosophy applied to safety critical systems such that the result of hardware failure or the effect of software error shall either prohibit the system from assuming or maintaining an unsafe state, or shall cause the system to assume a state known to be safe.

3.1.17 headway: The time interval between the passing of the front ends of successive vehicles or trains moving along the same lane or track in the same direction.

3.1.18 heavy rail transit: A mode of rail rapid transit generally characterized by fully grade-separated construction, operating on exclusive rights of way, and station platforms at the floor level of the vehicles.

3.1.19 interlocking: An arrangement of switch, lock, and signal devices that is located where rail tracks cross, join, separate, and so on. The devices are interconnected in such a way that their movements must succeed each other in a predefined order, thereby preventing opposing or conflicting train movements.

3.1.20 light rail transit: A mode of rail transit characterized by its ability to operate on exclusive rights-of-way, street running, center reservation running, and grade crossings, and to board and discharge passengers at track or vehicle floor level.

3.1.21 master control: The trainborne device or system directly providing the control signals to the train.

3.1.22 movement authority: The authority for a train to enter and travel through a specific section of track, in a given travel direction. Movement authorities are assigned, supervised, and enforced by a communications-based train control system to maintain safe train separation, and to provide protection through interlockings.

3.1.23 redundancy: The existence in a system of more than one means of accomplishing a given function.

3.1.24 reliability: The probability that a system will perform its intended functions without failure, within design parameters, under specific operating conditions, and for a specific period of time.

3.1.25 safe braking model: An analytical representation of a train's performance while decelerating to a complete stop, allowing for a combination of worst-case influencing factors and failure scenarios. A communications-based train control equipped train will stop in a distance equal to or less than that guaranteed by the safe braking model.

3.1.26 safety critical: **(A)** A term applied to a system or function, the correct performance of which is critical to safety of personnel and/or equipment. **(B)** A term applied to a system or function, the incorrect performance of which may result in a hazard.

NOTE—Vital functions are a subset of safety-critical functions.

3.1.27 service, revenue: **(A)** Transit service excluding deadheading or layovers. **(B)** Any service scheduled for passenger trips.

3.1.28 system safety: The application of engineering and management principles, criteria, and techniques to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

3.1.29 System Safety Program: The combined tasks and activities of system safety management and system safety engineering that enhance operational effectiveness by satisfying the system safety requirements in a timely, cost-effective manner throughout the system life cycle.

3.1.30 train: A consist of one or more basic operating units.

3.1.31 unit: *See:* basic operating unit.

3.1.32 vehicle: A land conveyance assembly for carrying or transporting people and objects capable of traversing a guideway, having structural integrity and general mechanical completeness, but not necessarily designed for independent operation.

3.1.33 vital function: A function in a safety critical system that is required to be implemented in a fail-safe manner.

3.2 Abbreviations and acronyms

ASCE	American Society of Civil Engineers
APTA	American Public Transit Association
ATC	automatic train control
ATO	automatic train operation
ATP	automatic train protection
ATS	automatic train supervision
CBTC	communications-based train control

MTBF	mean time between failure
MTBFF	mean time between functional failure
MTBHE	mean time between hazardous event
MTTR	mean time to repair
MTTRS	mean time to restore service
RF	radio frequency

4. General requirements

4.1 Characteristics of CBTC systems

The primary characteristics of a CBTC system include

- a) High-resolution train location determination, independent of track circuits;
- b) Continuous, high capacity, bidirectional train-to-wayside data communications;
- c) Trainborne and wayside processors performing vital functions.

4.2 Categorization of CBTC systems

This standard recognizes that different configurations of CBTC systems are possible, depending on the specific application. For example, a CBTC system may

- a) Provide ATP functions only, with no ATO or ATS functions;
- b) Provide ATP functions, as well as certain ATO and/or ATS functions, as required to satisfy the operational needs of the specific application;
- c) Be the only train control system in a given application, or may be used in conjunction with other auxiliary wayside systems.

A typical functional block diagram for a CBTC system is given in Annex B.

4.3 Range of applications

The CBTC performance and functional requirements defined in this standard are intended to be applicable to the full range of transit applications, including light rail, heavy rail, and commuter rail transit systems.

It is the intent of this standard that tiered levels of functionality, and interoperability between equipment provided by multiple vendors, are facilitated to the extent required by the authority having jurisdiction. All CBTC systems shall include ATP functions. ATO and ATS functions are optional.

4.4 Train configurations

A CBTC system shall be capable of supporting a variety of train configurations, including

- a) Fixed-length unidirectional trains comprised of one or more basic operating units;
- b) Fixed-length bidirectional trains comprised of one or more basic operating units;
- c) Variable-length unidirectional trains;
- d) Variable-length bidirectional trains.